Periodicity of the Blue-Green Algae

and Their Effect on the Efficiency

of Manure-Disposal Lagoons

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PREFACE

This publication reports on a research project and interprets the value received from the use of Public Law 480 funds to further the interest of the Agricultural Engineering Research Division of the Agricultural Research Service, specifically, and of the agricultural and scientific community of the United States, generally.

Public Law 480 funds are funds paid to the U.S. Government in return for goods and services and are retained within the country where collected. The countries using Public Law 480 funds are usually the developing countries with so-called soft currencies. These funds may be used in many ways to further the needs of the United States, but they must be used in the country of origin.

The final draft report for project A7–AE–6, "Animal Food Production From Waste Waters (Sewage)," by V. P. Singh, December 31, 1969, provided the base for this publication.

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INTRODUCTION

The research reported here was conducted at the National Botanical Gardens, Lucknow, India. It was part of an overall project to study the culture and harvesting of the various species of algae for use as a livestock feed. Algae have long been known as a good source of protein. In addition, they are efficient scavengers of plant nutrients in streams, ponds, and lakes. Their use has even been studied for possible application for waste recycling in space travel. In the past, however, commercial salvaging or harvesting of algae has been impractical. The primary reason for this has been the high costs of harvesting algae versus the costs of comparable proteinaceous feeds.

While this research was done on sewage-disposal lagoons, the findings are pertinent to livestock-waste-disposal lagoons. In addition, the findings will be of value to engineers who are concerned with the planning and design of sewage-disposal lagoons for small rural communities.

Other benefits that would be derived from the findings are:

● A new source of livestock feed.

● Removal of plant nutrients from waste water before it is discharged into public waterways and, consequently, minimizing algal blooms.

● Recycling of waste products, that is,
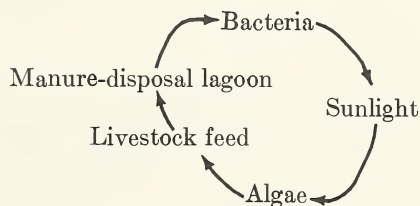
The value of the work that has been done is applicable in several relevant areas, such as waste-water renovations, plant-nutrient removal from waste water, livestock feed production via waste recycling and, to some extent, disease control. However, these results speculate on the possibilities of other, and perhaps more significant, developments that only await further research and refinement.

The research discussed took place in a zone between 25° and 27° N. latitude. This area of India would equate to the southern and western half of zone "A" shown as the shaded area on the zone map of the United States (fig. 1, p. 5).

PERIODICITY OF ALGAL FORMS IN RAW SEWAGE UNDER LABORATORY CONDITIONS

The purpose of this phase of the work was to determine the succession of the algal forms in still raw sewage under laboratory conditions.

Procedure

Raw sewage was collected at monthly intervals during the monsoon season. Fifty ml. aliquots were placed in 250 ml. sterilized cotton plugged Erlenmeyer flasks.[1] These flasks were maintained in a culture room under continuous fluorescent light of 2,000 lux, which is equivalent to approximately 200 ft.-c. Light-intensity requirements vary widely and are dependent upon such variables as algae population density, water temperature, vegetative stage of algae, and water turbidity.

For 5 months these cultures were removed aseptically at weekly intervals and examined for floristic compositions, after which they were allowed to dry.

The following tabulation of species of algae were identified in the cultures:

BACILLARIOPHYTA

Nitzschia palea (Kuetz.) W. Sm.

CHLOROPHYTA

Ankistrodesmus acicularis (A. Br.) Krosch.
Chlorella pyrenoidosa Chick.
Chlorococcum humicola (Naeg.) Rabenhorst
Cosmarium sp.
Pediastrum boryanum (Turp.) Menegh.
S. guadricauda (Turp.) Breb.
Scenedesmus obliguus (Turp.) Kuetz.
Schizomeris leibleinii Kuetz
Tetraedron triangulare Krosch.

CHRYSOPHYTA

Synura uvella Ehr. emend Korsch

CYANOPHYTA

A. fertilissima v. tenuis Rao
Anabaenopsis circularis (G.S.West) Wolosz. et Miller
Aphanothece gelatinosa (Henn.) Lemmermann

Aulosira fertilissima Ghose
Cylindrospermum gregarium (Zakrz.) Elenk.
Dichothrix gypsophila (Kuetz.) Born. et Flah.
Gl. decorticans (A.Br.) Richter.
Gl. magma (Breb.) Kuetz.
Gloeocapsa atra'a (Turp.) Kuetz.
Hapalosiphon welwitschii W. et G.S. West
Lyngbya hieronymusii Lemm.
L. hieronymussi f. robusta Parkutty
L. lagerheimii (Moebius) Gom.
Merismopedia punctata Meyen
Microchaete uberrima Carter
Myxosarcian spectabilis Geitler
N. piscinale Kuetz ex Born et Flah.
Nostoc ellipsosporum (Desm.) Rabenh. ex Born. et Flah.
Oscillatoria subbrevis Schmidle
Phormidium corium (Ag.) Gom.
Scytonema sp.
Synechococcus aeruginosus Naeg.
Tolypothrix distorta Kuetz. ex Born. et Flah.
Westiellopsis prolifica Janet

EUGLENOPHYTA

E. viridis Ehr.
Euglena pisciformis Klebs
Phacus pleuronectes Duj.

No algae developed in the first week. After 10 days, mixed blooms of Euglena, Phacus, Synura, and Nitzchia were observed. Species of Euglena were the most dominant during this period. Later on, the growth of these species gradually declined and the species of Gloeocapsa became dominant. These algae were found adhered to the sides and bottoms of the flasks.

The unicellular and colonial forms of algae disappeared after 2 months then mixed culture of Oscillatoria subbrevis along with the species of Cosmarium, Ankistrodesmus, Pediastrum, Aphanthece, and Merismopedia developed. Thereafter, Oscillatoria subbrevis was the only form growing profusely for 3 weeks, while other species declined and ultimately disappeared. Simultaneously, the growth of the species of Nostoc, Chorella, and Scenedesmus started appearing in the cultures. These forms grew well for 6 weeks, after which the members of Chlorophyta disappeared from the cultures. As soon as this happened, the members of Cyanophyta, specially those of Nostocales and Stigonematales, started appearing and finally became dominant. Anabaenopsis circularis, Nostoc ellipsosporum, Hapalosiphon welwitschii, and Westiellopsis prolifica were the most common forms.

The growth of these forms continued and the flora did not change appreciably until the cultures dried.

These findings show that the members of Chlorococcales, Euglenophyta, and colonial, as well as nonheterocystous forms of blue-green algae, require high concentration of organic matter for growth. But the heterocystous forms thrive well in cultures under comparatively low concentration of organic matter. The heterocystous forms of algae apparently are less dependent upon the carbon dioxide (CO_2) resulting from the breakdown of organic material for metabolism, even though they are of the "blue-green" family and thereby presumed to have some capacity for photosynthesis.

The chlorococcalis and euglenophyta, on the other hand, are green forms of algae capable of photosynthesis and, therefore, definitely require CO_2 for their metabolism. As with terrestial plants containing chlorophyl (green coloring), elevated levels of CO_2 during the growing period produce greater yields of plant material.

Under constant and uniform conditions of light and temperature, the various species of algae are self-limiting in their growth cycles. This finding is significant in that: (1) Total available nutrients may not be, and probably are not, consumed, probably because of the succession of dominant varieties of algae; (2) the species of algae that has peaked in dominance and is dying must be removed from the media or it becomes a polluting agent; (3) since the environmental conditions have remained constant, the decline of any given species of algae must be due to the waste products given off by that particular species. That the waste products of the other species present can be the causative agent is discounted because these species in turn become the dominant species, each superseding another.

Table 1 shows the species of algae found during the different months in outdoor or natural conditions. The variables here are temperature, seasonal variation, and light (intensity and duration). In general, the chlorella (sp) preferred the cooler months while the blue-green algae preferred the warmer ones.

TABLE 1.—*Seasonal distribution of algae growing on brick lining of oxidation ponds*

Species	Growth period	Species	Growth period
A. longissimus var. acicularis (Chod.) Brunnth.	March.	Eudorina elegans Ehr.	January, February, April.
A. longissimus (Lemm.) Wille	February.		
Actinastrum hantzschii Lagerh	June.	Euglena acus Ehr.	March.
Ankistrodesmus acicularis (A.Br.) Korsch.	March.	Gomphonema angustatum var. productum Grun.	December.
Anomoeoneis sphaerophora (Kuetz.) Pfitz.	February–June.	Lyngbya martensiana Menegh.	February–April–June–November.
C. meneghiniana Kuetz.	January–June, November–December.	M. islandica O. Mull.	March–May.
		M. italica (Ehr.) Kuetz.	March.
C. sp.	February.	M. italica var. tenuissima (Grun.) O. Mull.	February–March.
C. stelligera Cl. et Grun.	February–December.	Melosira granulata (Ehr.) Ralfs	February–April, June–November, December.
Chloroplana terricola Hollerb.	March.		
Closterium moniliferum (Bory) Ehr.	March.		
Coccomonas orbicularis Stein.	February.		
Cocconeis placentula var. intermedia (Herib. et Perag.) Cl.	April.	Merismopedia punctata Meyen.	May–June–November.
Coelastrum microporum Naeg.	April–June.	Microcystis aeruginosa Kuetz.	May–November.
Cyclotella kuetzingiana Thwait.	February–March.	Myxosarcina spectabilis Geitler.	April–July–September.
Cymbella lata var. minor Molder	March–June.		
D. simplex Korsch.	February.	N. cocconeiformis Greg.	April.
Dictyococcus mucosus Korsch.	March–April.	N. cryptocephala Kuetz.	December.
Dictyosphaerium pulchellum Wood.	March.	N. cuspidata var. ambigua (Ehr.) Grun.	January–May.

TABLE 1.—*Seasonal distribution of algae growing on brick lining of oxidation ponds*—Continued

Species	Growth period	Species	Growth period
N. halophila f. *subcapitata* ostr	February–April, June–November.	*Oscillatoria amoena* Gom	February–April–June.
N. halophila (Grun.) Cl	April–May.	*P. acuminatus* Stokes	April.
N. intermedia Hantzsch	March.	*P. molle* f. *tenuior* G.S. West	March–July.
N. kuetzingiana Hilse	April–May.	*P. molle* (Kuetz.) Grun	March.
N. menisculus Shcum	March.	*P. mucicola* Hub.-Pest. and Naumann	June–August–September–November.
N. microcephala Grun	May.		
N. palea (Kuetz.) W.Sm	February.		
N. palea var. *capitata* Wisl. et Poretzky	June–November, December.	*P. savanensis* Boye P	March.
		P. sp	February.
N. pupula Kuetz	February–March, November–December.	*Pandorina morum* Bory	February–June.
		Phacus pleuronectes Duj	March.
N. pygmaea Kuetz	February.	*Phormidium foveolarum* Gom	March–May–November.
N. sublinearis Hust	February.	*Pinnularia braynii* var. *amphicephala* (A. Mayer) Hust.	November–December.
N. thermalis Kuetz	January–May.		
N. thermalis var. *minor* Hilse	March.	*Pyrobotrys gracilis* Korsch	February–March.
Navicula cincta (Ehr.) Kuetz	March.	*Rhopalodia gibba* (Ehr.) O. Mull	February.
Nitzschia amphibia Grun	June.	*S. bijugatus* (Turp.) Kuetz	February–April–June.
O. amphibia Ag	May–July–September–October.		
		S. obliquus var. *alternans* Christjuk	March.
O. brevis (Kuetz.) Gom	October.	*S. obliquus* (Turp.) Kuetz	April–May.
O. chalybea f. *conoidea* V. Poljansk	March.	*S. ovata* Kuetz	December.
O. chalybea (Mert.) Gom	April–May July.	*S. protuberans* Fritsch	February–April.
O. chlorina Kuetz	March–June–August–September–November.	*S. quadricauda* (Turp.) Breb	January–October.
		S. ulna var. *aequalis* (Kuetz.) Hust	March.
O. formosa Bory	May–July August.	*Scenedesmus acuminatus* var. *biseriatus* Reinh.	January–June–October.
O. granulata Gardner	August–November.	*Selenastrum minutum* (Naeg.) Collins	March.
O. irrigua Kuetz	February–June.	*Sphaerocystis schroeteri* Chod	February.
		Spirulina major Kuetz	January–February–April–August–October.
O. pseudogeminata G. Schmid	July.		
O. subbrevis Schmidle	March–July–September.		
O. submarina Lagerh	January–February.	*Surirella angustata* Kuetz	December.
O. tenuis Ag	August.	*Synedra ulna* (Nitz.) Ehr	March.
O. tenuis f. *uralensis* (Woronich.) Elenk	July.	*Tetraedron triangulare* Korsch	February.
Oocystis pusilla Hansg	March.	*Trochiscia granulata* (Reinsch) Hansg	February–March.

CLIMATIC COMPARABILITY BETWEEN INDIAN RESEARCH AREAS AND THE UNITED STATES

Table 2 and figures 1 and 2 show the geographical and climatic and population data for the area covered in this research. Figure 1 is a map of the actual geographic area covered, and figure 2, a map of the United States showing a roughly comparable climatic area.
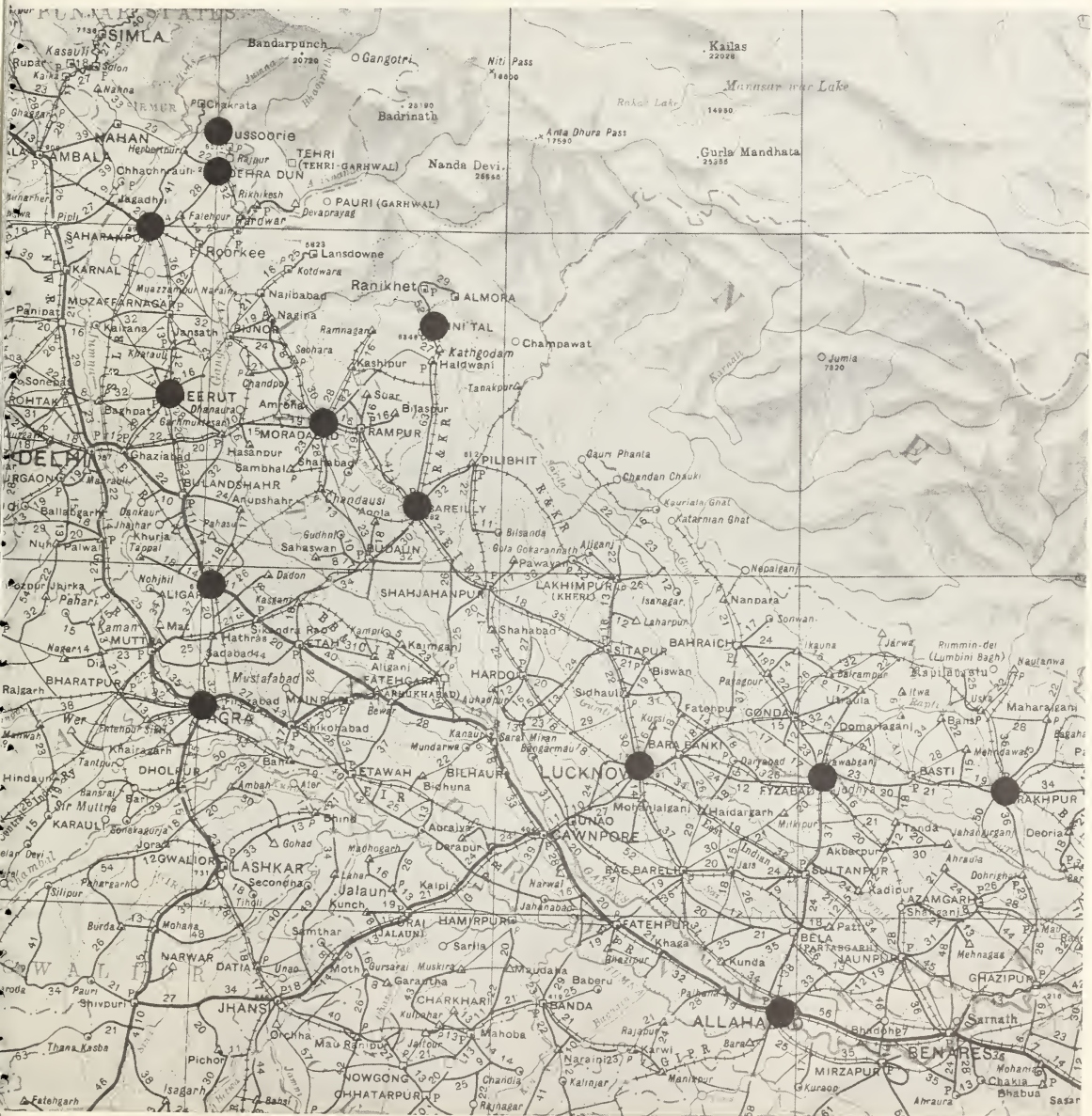

FIGURE 1.—North-central section of India where research was conducted.
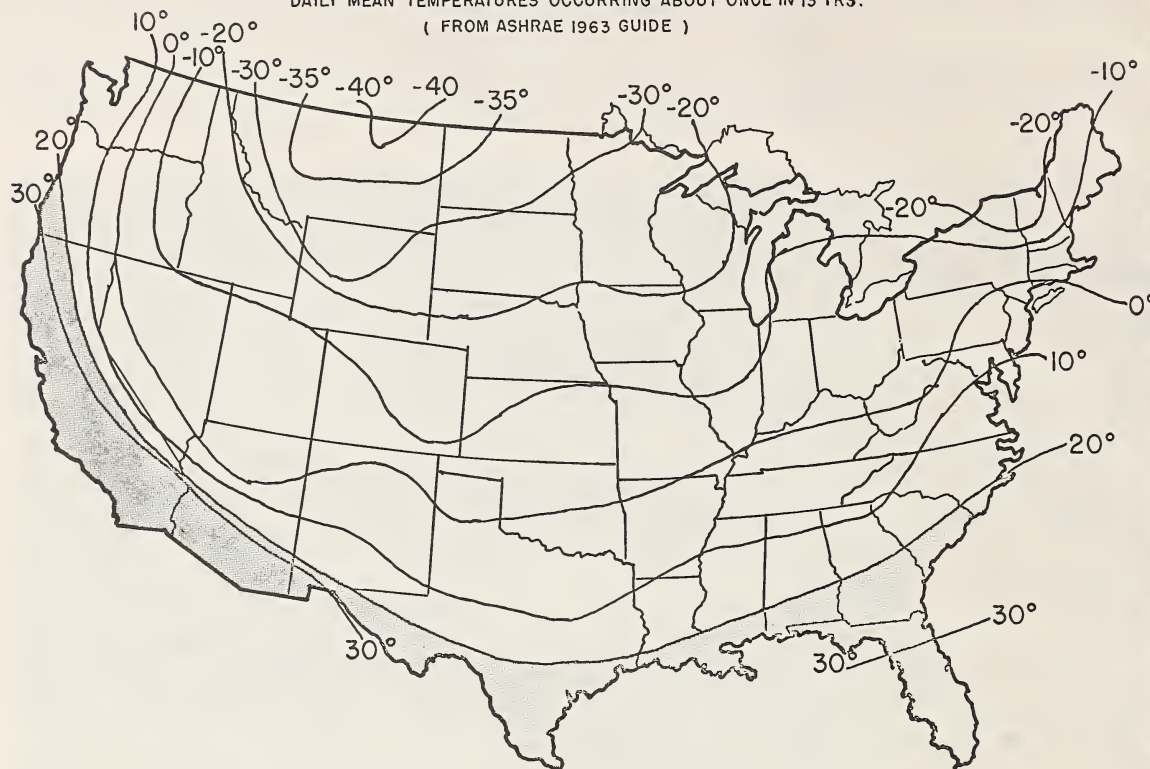
FIGURE 2.—U.S. area of climate comparable to sectional map of India where research was conducted.

TABLE 2.—*Physiographic, climatic, and population data of towns in Uttar Pradesh*

Place	Latitude	Longitude	Altitude (approx.)	Temperature range		Mean annual rainfall	Population
				Maximum	Minimum		
			M.	*° C.*	*° C.*	*Mm.*	*Thous.*
Agra............	27°10′	78°3′	157	47.5 & above	−2. 5–0	662. 9	508
Aligarh........	27°53′	78°4′	186	do	−2. 5–0	627. 6	185
Allahabad......	25°26′	81°50′	96	do	0–2. 5	976. 4	431
Bareilly........	28°22′	79°24′	178	45. 0–47.5	−2. 5–0	1, 080. 0	273
Dehra Dun.....	30°19′	78°2′	615	42.5–45.0	−2. 5–0	2, 056. 9	156
Faizabad.......	26°47′	82°10′	116	45.0–47.5	0–2. 5	1, 053. 3	88
Gorakhpur.....	26°45′	83°22′	79	do	0–2. 5	1, 245. 1	180
Kanpur........	26°28′	80°21′	138	47.5 & above	0–2. 5	840. 7	971
Lucknow........	26°52′	80°56′	120	45.0–47.5	0–2. 5	1, 006. 8	656
Meerut........	29°1′	77°43′	234	47.5 & above	−2. 5–0	801. 9	284
Moradabad.....	28°51′	78°46′	197	45.0–47.5	−2. 5–0	944. 3	192
Mussoorie......	30°27′	78°5′	2, 020	42.5–45.0	−2. 5–0	2, 540. 0	10
Naini Tal.......	29°24′	79°28′	1, 965	do	−2. 5–0	2, 690. 1	16
Saharanpur.....	29°57′	77°33′	274	45.0–47.5	−2. 5–0	949. 3	185
Varanasi........	25°18′	83°1′	84	47.5 & above	0–2. 5	1, 078. 5	490

APPLICATION

This research indicates that the self-limiting tendencies of the blue-green algae studies, and probably others of that family, could be used advantageously.

By knowing the species that follow one another in the succession of population predominance, it might be possible, for example, to anticipate a peak in the population of species "A" and follow that peak with an innoculation of species "B" that normally follows in population-peaking cycle. Species "C" would follow species "B" peak and so on.

Seeding would be used to accelerate the nutrient uptake so that the ultimate effluent would be practically nutrient free. Thus a greater harvest of algae would be achieved with a desirable species predominant with fewer wild strains that might have undesirable qualities. Harvesting algae would have two purposes:

1. To remove organic matter from the waste water as soon after it is produced as possible to prevent the organic matter from becoming a pollutant when its population peaks and wanes.

2. To serve as a potential livestock and poultry feed in countries and areas where conventional feeds are unavailable, required by humans, or prohibitively expensive.

As a cultural procedure, passing the waste-laden effluents through a series of detention ponds might be desirable and practical. Each pond theoretically would be a culture area for algae species A, B, C, and so on in sequence.

In general, the purpose of this publication is to give the sanitary and agricultural engineers and the biologists a starting point from which to either expand on the production of feed or food or strive for the greater purification of waste water via the biological route.

DISCUSSION

The research reported, interpreted, and evaluated here was performed in India under the provisions of Public Law 480 which provided the necessary funds.

Mr. Eby, the sponsoring scientist, communicated regularly with the Indian researchers working on this project. Guidance provided by the sponsoring scientist was instrumental in achieving positive results.

Periodicity findings can explain peculiarities observed in nature, that is, the "Red Tide" commonly seen in the Gulf of Mexico, and may eventually lead to solutions.

Sequential peaking of algal species in a body of water reemphasize that any given life form can kill itself off if its own waste products are not removed from its immediate environment.

Finally, the periodicity of the specifically identified algae show that a given body of waste water is capable of producing a much greater volume of potentially valuable feedstuffs than might have been previously suspected *if proper management procedures are carried out.*